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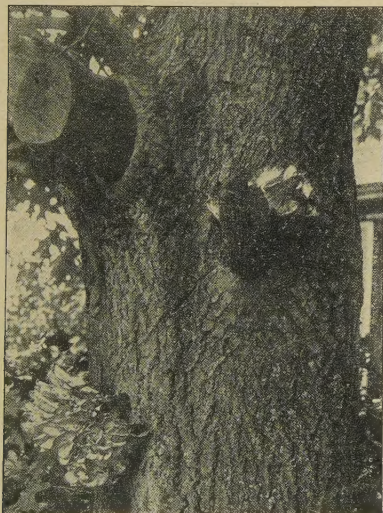
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BOTANICAL DIVISION.

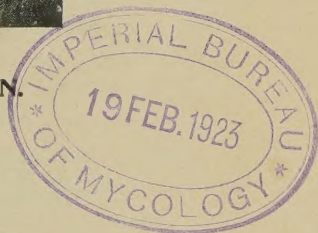
Studies of Some Shade Tree
AND
Timber Destroying Fungi.



By GEO. F. ATKINSON.

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STUDIES OF SOME SHADE TREE AND TIMBER DESTROYING FUNGI.*

BY GEO. F. ATKINSON.

A great deal of attention has been given in the past to the study of injuries to trees caused by the microscopic fungi, but comparatively little study has been made of the relation of the larger fungi to the destruction of trees and timber. The most notable work which has been accomplished in this direction is that of Robert Hartig of München, Germany, whose contributions have appeared in the publications of the "Forstliche Versuchsanstalt," in his book on the Diseases of Trees, and in other places. During the past two years there have appeared several excellent bulletins from the Missouri Botanical Garden and from the U. S. Dept. of Agr., giving in detail the results of some work by H. vonSchrenk, of Washington University, St. Louis.

About five years ago the writer began studying the injuries which some of the higher fungi produce upon shade trees and timber trees. Very little of this work has as yet been published. Use has been made however of some of the studies and photographs accumulated in the progress of the work, in the author's "*Mushrooms; Edible, Poisonous, Etc*" (1900), and in other places; while a short article was published on "Some Wood Destroying Fungi," as special report No. 9 in the Geological Survey of Louisiana, Feb. 1900. It has been my plan as far as possible to select one or more individual cases and then endeavor to trace the history of the relation of the fungus and its host. This would include a study of the present conditions, and an effort to determine, by examination, the time in the past when the fungus entered, the mode of its entrance and progress, as well as the probable cause of the wound which provided the entrance court for the tree enemy. In a number of cases these

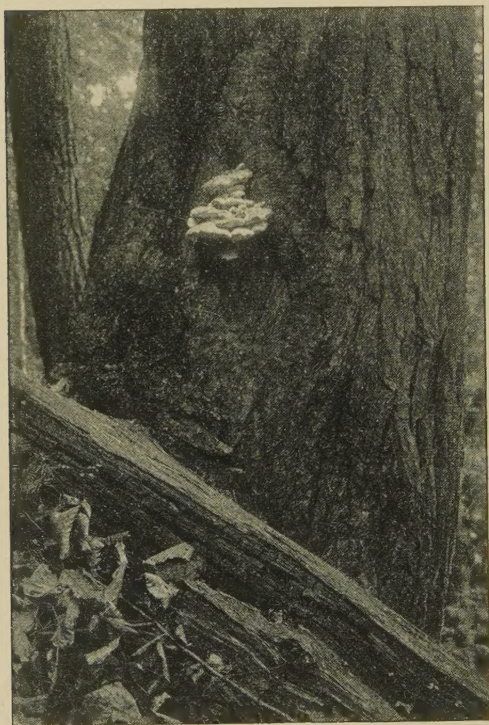
* The principal facts in this paper were presented before the Mass. Hort. Soc., Boston, Mar. 1901.

have been worked out quite satisfactorily. The studies have been made in New York State, chiefly at Ithaca and in the forests of the Adirondack Mountains.

A word might be said at the outset in regard to the relation of these wood destroying fungi to others, as well as in regard to their structure. They are among the higher fungi and belong to the larger group known as the *Hymenomycetes* to which the mushroom also belongs. In fact it is becoming customary with

some to apply the term "mushroom" to all of the *Hymenomycetes*. However widely these plants differ in their form and structure they all agree in the general character of their fruiting surface. It forms a thin layer or "membrane," covering definite parts of the fruit body, and consisting of innumerable club-shaped cells standing side by side. Each one of these club-shaped cells is called a *basidium*, and usually bears four spores.

There are several large families, or orders in the group. I will call attention to a very few in each



56.—*Polyporus borealis*. Fruit bodies growing from wound on hemlock spruce.

family in order to show more definitely the form and general character of the species examined here. In one of these families the fruit body is often spread over the surface of the wood in

thin smooth patches, or some forms are shelving, when the under-side is smooth and is the fruiting surface. These belong to the family *Thelephoraceæ*. A few of its members are very destructive to wood and some are parasites on trees. In another family the members are known as "coral fungi," or "fairy clubs" a large number of them belonging to the well known genus *Clavaria*, from which the family name *Clavariaceæ* is derived. The fruiting surface is distributed all over the surface of the plant. To a third family, *Hydnaceæ* belong the "hedgehog fungi," with the fruiting surface on spines, a few species of which are well known. A number of the members of the two last named families grow on wood, but often appear in late stages of decay. A few species like *Hydnum septentrionale* on maple, and *H. schiedermayeri* on apple, are destructive.

The two largest families are known as the *Agaricaceæ*, to which the common mushroom belongs, and the *Polyporaceæ*. In the latter the fruiting surface is in the form of a honey-comb on the under side of the fruit body. It is to this last named family that the species belong which are treated of here.

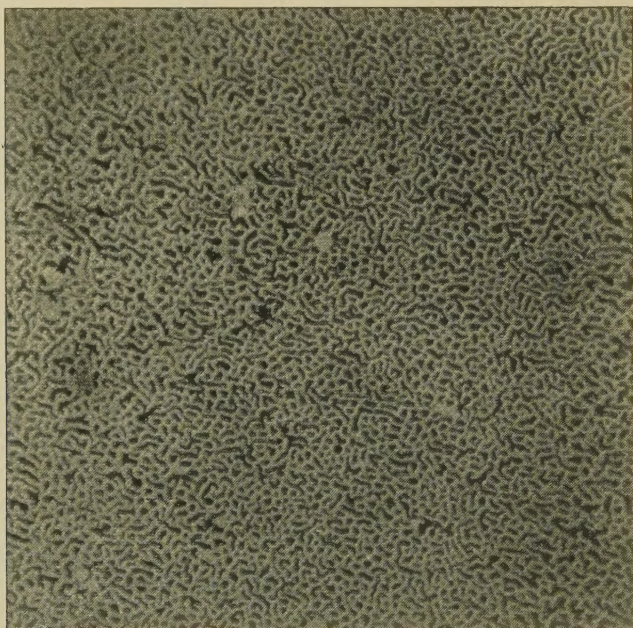
The gross characters, those which are quite easily made out without the aid of a microscope, are chiefly the ones presented here, since a detailed account of microscopic structures and changes brought about in the wood by the action of the fungus, are rather too technical for full treatment in this paper.



57.—*Polyporus borealis*, section of fruit body.

POLYPORUS BOREALIS.

Polyporus borealis occurs on pines, spruces, the hemlock, etc., and is widely distributed over the North Temperate Zone. It occurs on living or dead trees. It is a "wound" parasite, entering through broken branches, through wounds caused by impact of falling timber, or where the cambium has been scorched by fire. The fruit bodies are entirely white. When



58.—*Polyporus borealis*, *Hymenium with sinuous pores*.

old or dry they often take on a pale yellowish tinge. They are shelving, the cap attached directly to the tree, broad at the free end and tapering somewhat in a wedge-shaped manner toward the base. They are rarely single, and sometimes scattered over the trunk. They usually occur, several close together overlapping in an imbricated fashion, and joined at the base in a common trunk at the exit from the tree.

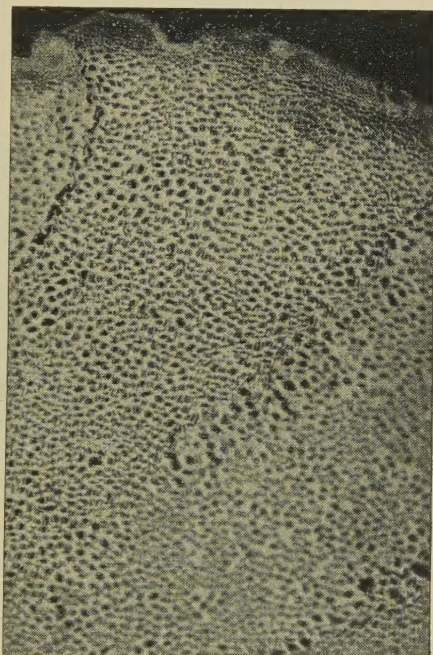
The fruit bodies are rather soft and spongy. They last only for the season. They are 10 to 20 cm. (4 to 8 inches) long by 6 to 15 cm. broad. They form larger masses where several are joined. The upper surface is rough with coarse tufts of mycelium giving it a very shaggy or sodden appearance. The honey-combed surface is below. The hymenium consists of quite regular pores with rounded openings in some specimens, or irregular, elongated and sinuous pores in other specimens, resembling the pores of *Dædalea*. But they are evenly sunk in the substance of the cap and therefore lack the essential character of that genus. The walls of the pores are thin, and the edges often irregular and jagged.

There are two cases of its occurrence on living coniferous trees which I have carefully studied. One case is that of a hemlock spruce (*Tsuga canadensis*). The other is that of a red spruce (*Picea rubra*), the common timber spruce of the Adirondack region.

The hemlock spruce was a large tree, 60 cm.

(2 ft.) in diameter, on a steep slope in one of the deep gorges (Fall Creek) at Ithaca, N. Y.

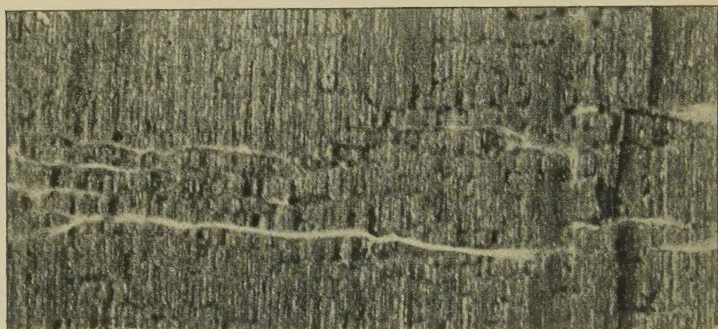
This example was observed in the autumn of 1899. The fruit body of the fungus was situated at a large wound on the trunk near the base. It consisted of several caps closely joined at their origin from the trunk of the tree. This is well shown



59.—*Polyporus borealis*, Hymenium with rounded pores.

in the several photographs. A section through the entire fruit body (Fig. 57) shows the radiating lines formed by the general direction of the mycelium in the caps from their common origin in the tree trunk.

One of the photographs gives us a clue to the manner in which the mycelium of the fungus entered this particular tree. The log, lying in the foreground, close by the trunk of the affected tree, tells the tale. This tree in its descent, years ago, struck the slightly projecting base of the standing hemlock, and knocked off a large area of the bark and cambium, or growing region, at this spot. This wound was too large and the tissues



60.—*Polyporus borealis*. Disintegration of wood.

too much bruised to permit rapid healing over. It offered therefore a sure infection court through which the mycelium entered.

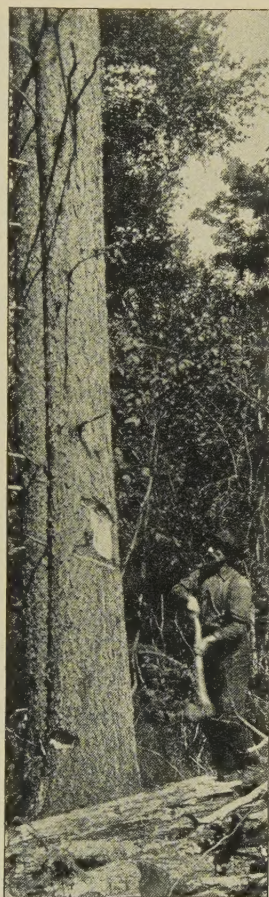
This also shows that the healing has been going on for a long time from the margin of the wound. But the wound is so large, it is yet far from being healed. Had it later healed over, it could not, of course, save the tree from destruction because the wound parasite was already permanently established in the interior, or heart, wood. Thus the wound which gave entrance to the fungus mycelium also offers a place for its exit in the formation of the fruit body.

From the time the mycelium entered the trunk at this wound, which must have been from 25 to 40 years ago, the mycelium gradually made its way into the heart, and from there grew downward into the roots and upward through the heart to the

top of the tree. Its presence on the roots was determined by the occurrence of the fruit bodies from a few places on exposed parts of the large roots, while external evidence of its having reached the top of the tree was shown by a number of dead limbs in the top, some of which had fallen. Evidence of its having reached the top was also found on cutting down the tree, and taking out sections at different points in the trunk. Here was found an abundance of mycelium and the heart wood was in an advanced stage of decay.

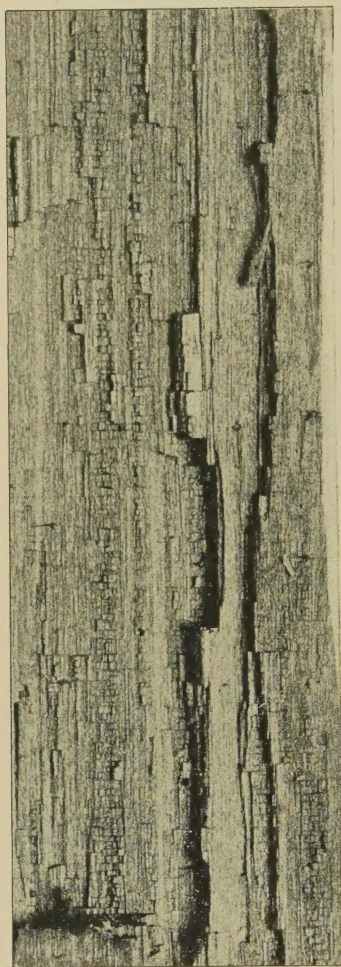
The mycelium advances in certain definite directions in the wood of the tree. This is probably due to the structure of the wood. It grows in three different directions: parallel with the axis of the tree trunk, *i. e.* up and down; radially, from the center toward the periphery; and tangentially. At one stage of development the mycelium may be very profuse and abundant. It then is present in the form of cords or strands which lie radially or tangentially in the channels which have been dissolved by the action of the fungus ferment on the wood. These strands lie quite close together and are parallel. After being developed in considerable abundance the strands of mycelium largely disappear having burrowed open channels and furrows through the wood in the radial and tangential directions.

Shrinkage of the wood occurs at the same time because of the disappearance of a considerable content of the water and of the wood substance. This shrinking results in checking the wood into numerous minute cuboidal blocks, marked off primarily by



61.—Red spruce affected with *Polyporus borealis*.

the position, and solvent action, of the mycelium. This becomes more pronounced if the wood dries, if the tree is cut or if blocks



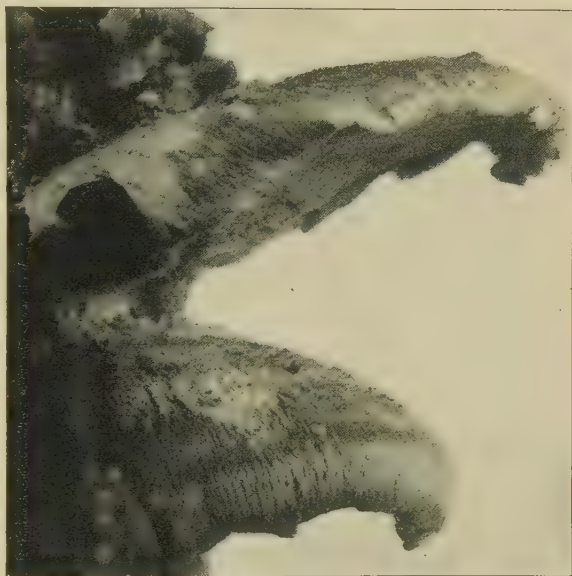
62.—Effect on wood of red spruce by the mycelium of *Polyporus borealis*.

of the wood are cut from the trunk and allowed to dry. In the early infection of the wood, and the early stages in the advance of the mycelium, before the larger strands have become established, the openings made by the mycelium are very minute. They take the same directions as the larger openings. In fact the mycelium, instead of making a general attack upon the tissues, begins its advance at certain regularly separated points, and then extends along in parallel lines. If the wood is cut out at this early stage, one can see these minute perforations thickly scattered over the exposed surface. Sometimes, even in this early stage, shrinkage of the wood will have taken place. If not very marked when freshly cut from the wood, the shrinkage of the wood on drying, marks it off in a beautiful manner, by fine lines and holes into cuboidal areas.

In many of these cases of the heart rot of trees, after the heart wood is well affected, the mycelium being well established and vigorous, gradually encroaches on the cambium or living area beneath the bark. In this way, many of the branches in the top of the tree die, and in some cases later the cambium of the trunk may be so destroyed as to kill the tree outright.

The red spruce example, in the Adirondack woods, was a tree of handsome proportions near Pearcefield Falls, in the Raquette River, left by the lumberman a few years prior to 1896, the season when I observed the tree. At some distance there was no indication that the tree was diseased and I enquired of my guide, who had at one time some experience in cutting timber, why the tree was left. "That tree ain't no good," he replied.

As we approached nearer, he said, "don't you see the gum running from all the knot holes?" This he explained was regarded as a sure sign of "heart rot." Furthermore the tree was "checked" on one side, the crack being quite large and extending for some dis-



63.—Fruit bodies of *Polyporus borealis*, showing shaggy cap.

tance. The check was probably caused by a wrench given the weakened tree during a heavy wind. There was no other external evidence that the tree was diseased, and to satisfy myself that the tree suffered from "heart rot," I had my guide cut out a few blocks of the wood from the trunk. Two inches beneath the bark, the wood was found in a "dozed" condition. The heart was not in a very advanced stage of decay though the area was very extensive. The mycelium visible to the eye was very scanty. Still the wood showed numerous fine perforations, and

as some shrinkage had taken place, it presented the very fine divisions into minute blocks described above. I then searched more carefully for some fruit form of the fungus and found at the ground level, buried under leaves, a fruit body of the *Polyporus borealis* between two buttresses of the base of the trunk. The tree was not felled, and consequently there was no opportunity of ascertaining the special mode of infection in this case.

POLYPORUS SULPHUREUS.

The sulphur polyporus has a very wide distribution and occurs on a great variety of broad leaved trees as well as on certain of the conifers. It is known on the apple, walnut, butternut, locust, oak, ash, pine, hemlock spruce, and other trees. It occurs on living trees, the fruit bodies growing from knot holes or wounds from the mycelium in the heart of the tree; or the fruit bodies arise from portions of the trunk killed by the fungus. It is also a very common fungus on dead and decaying logs, stumps and roots.



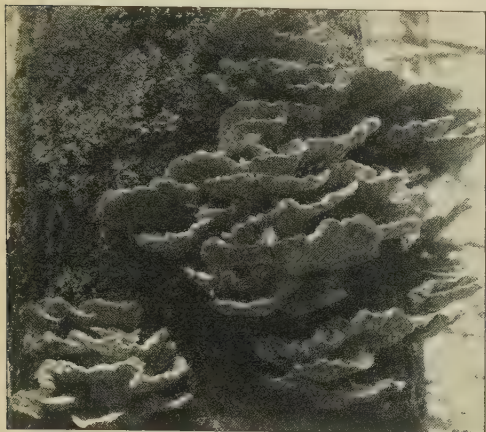
64.—*Polyporus sulphureus*.
Large tubercular fruit body
on oak.

The plant is easily recognized by the yellowish color of the caps which are of the shelving form, sometimes scattered, but more often closely overlapping. Sometimes the caps are so closely crowded as to form a large tubercle 20 to 25 cm. or more in diameter. The upper surface of the cap is a bright orange red, while the lower surface, the honey-combed fruit surface, is sulphur yellow. The fruit bodies are rather soft, the color soon fades, they are quickly attacked by insects, or decay after several weeks. They are short lived therefore, while the mycelium within the trunk is perennial, or at least lives from year to year without an annual infection.

OAK TREE KILLED BY POLYPORUS SULPHUREUS.

A scarlet oak tree (*Quercus coccinea*) growing near the grounds

of Cornell University was under observation for several years. The tree was standing on the edge of the Fall Creek gorge, not far from the Fisk McGraw mansion and opposite the present electric power plant of the Ithaca Street Railway. It was first observed in 1897. At this time the mycelium of the sulphur polyporus had advanced so far from



65.—*Polyporus sulphureus*. Scattered fruit bodies on living oak.

the heart wood into the sap wood, that the latter, as well as the cambium layer, on one side of the trunk near the base, had been killed. This gave an opportunity for the exit of the fungus and the formation of the fruit bodies on the outside. Fig. 65 is from a photograph taken in 1897. They are fine specimens, but are much more scattered than is usual with this species. The fruit bodies appeared during the succeeding seasons of 1898 and 1899. During the latter season the tree died from the injuries of the mycelium in its advance on the cambium or living portion of the trunk. It was felled, and several sections cut out from the trunk for observation.

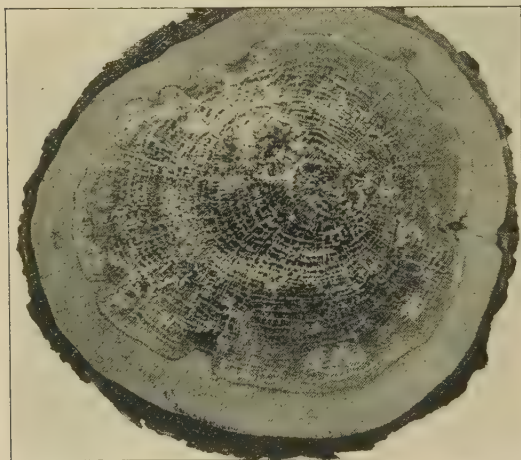


66.—“ Punk ” in cracks on oak log.

The decay of the heart wood had reached an advanced stage so that it was quite soft, and the moisture content was much less than in healthy trees. The lessening of the water content of the heart wood during the growth and spread of the mycelium caused a shrinkage in the wood. This produced several radial checks into which the mycelium had grown forming sheets of pure mycelium, sometimes called "punk."

POLYPORUS SULPHUREUS IMPRISONED IN A WHITE OAK.

A white oak tree about 40 years old was growing quite close by the side of a larger tree on the grounds of Cornell University.



67.—Section of living oak with imprisoned mycelium of the sulphur polyporus.

The tree leaned slightly away from the larger one and there was a one sided development of the branches induced by stronger illumination from that side.

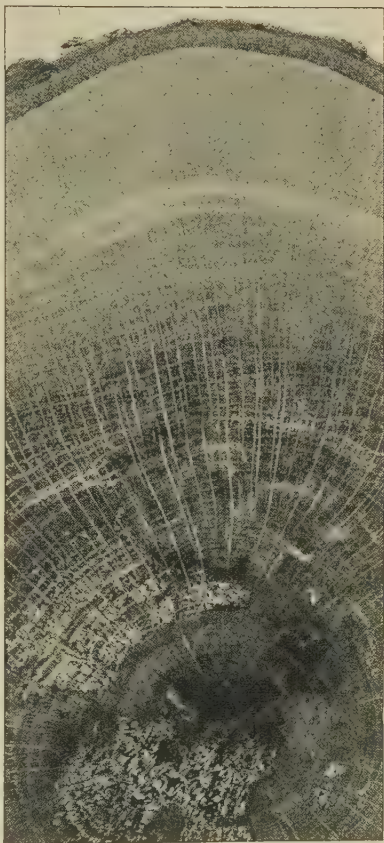
The tree was felled in order to see if there was a corresponding asymmetry in the annual growth of the trunk which might be manifest in the excentric

position of the annual rings. Before cutting the tree down there was no evidence that it was diseased. The trunk to all external appearance was sound. There were no broken limbs, no wounds, visible. On cutting the trunk into sections to study the annual rings, the heart wood through a large part of the trunk presented unmistakable evidences of partial decay following many of the annual rings and along by the medullary rays. The wood in these areas was being disorganized by the mycelium, and the latter forming the incipient stages of punk.

The case was an interesting one since the question arose as to how the fungus, now completely imprisoned, gained entrance to the trunk. The butt was sound so the fungus could not have entered through the roots.

Perhaps it entered at a large branch broken a number of years ago and now completely healed over.

All of the sections showed more or less decay at the central core of the heart wood where some of the wood was so badly decayed in some sections as to break out or crumble from the friction of the saw. One of the sections not far from the base of the trunk presented on the lower end, and near the periphery, a circular black area, resembling the dead remnant of a branch which might have broken off years ago, and healed over. On the surface of the same side of this section was a prominent enlargement in the trunk, resulting from the healing process. But the evidence of a wound here was largely obliterated because the old bark had formed over the surface. There was only a minute opening, very obscure which was not completely healed over.

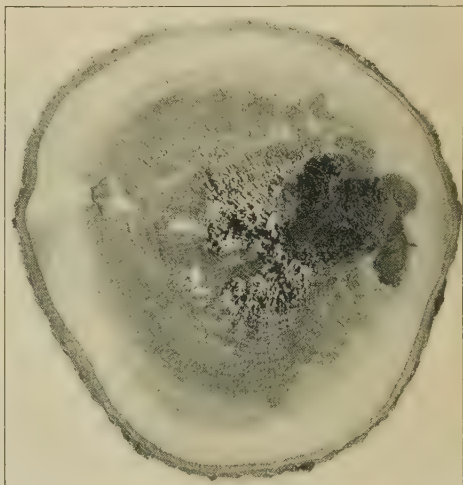


68.—Section of oak showing decay at center.

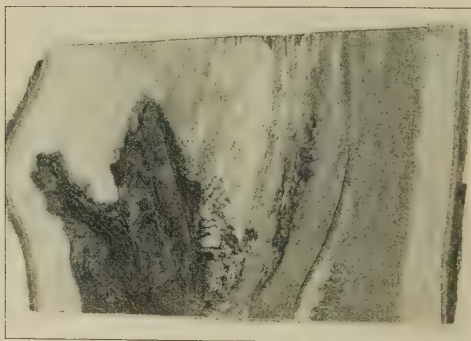
By examining successive sections of the trunk below this one it was observed that this black "core" representing the broken portion of the young tree gradually came to lie exactly in the central core of the trunk. This indicates quite clearly that the

injury occurred to the tree in the sapling stage, and that the sapling was broken off instead of one of the branches. One of the upper branches then became the "leader" and in course of time the broken end of the sapling was enclosed by the healing tissue.

This section of the trunk was then sawed through lengthwise and in such a direction as to split the core of the dead sapling radially from the center of the new trunk. A view of one-half of this section is shown in Fig. 70. It shows the origin of the branch which became the new "leader" of the tree; as well as the large and irregular



69.—Section of oak showing dead sapling stage near center.



70.—Section of oak showing slivered end of broken sapling.

end of the broken sapling covered over by the healing tissue.

The cross section shows that this injury occurred more than 30 years ago, very near the time that Cornell University was founded. Some accident, the cause of which we cannot now determine, befell this tree in its

youth and the sapling was broken off, while one of the topmost remaining branches in time replaced the main trunk.

An injury resulting from this kind of fractures leaves a long and slivered end some distance from the point where healing takes place. It must be a number of years then before the healing process can advance so far as to cover the fracture. In



71.—*Polyporus igniarius*, tongue form of fruit body on beech.

this instance over thirty years elapsed. The broken and slivered end of the sapling offered the most favorable lodgement place for spores of fungi, and for the accumulation of detritis resulting from the constant weathering of the exposed surface. In these places moisture is also conserved. The conditions presented are favorable for the germination of the spores and entrance of the mycelial threads. No more favorable infection court could be provided whereby the fungus is

enabled to enter the heart wood.

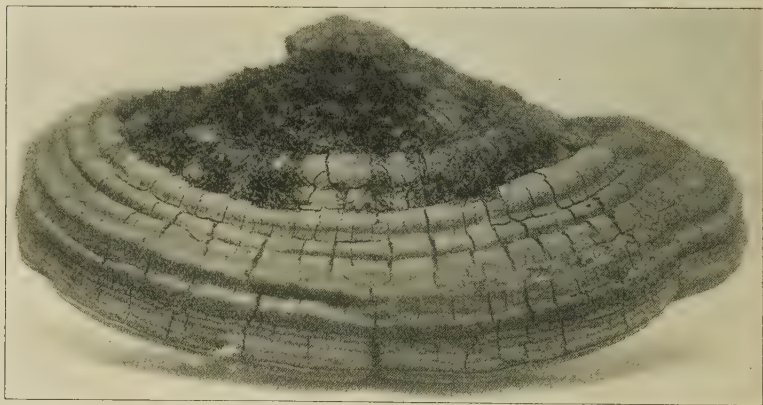
From this point of infection the mycelium spreads both ways down the old trunk of the sapling, and upward in the branch



72.—*Polyporus igniarius*. Hoof form on beech.

which forms the newly established leader. The progress of the fungus is comparatively slow, and the disorganization of the wood accompanies it. The slow growth of the mycelium is

probably due to several causes, the resistance which it meets from the wood, the action of tannic acids in the heart wood, as well as to the small amount of air in the interior of the tree. When sections of the trunk were cut, and piled together, the mycelium at the cut surfaces grew very rapidly. The mycelium here had access to air, and the moisture was conserved by the cut surfaces being in contact. In this way it was easy to demonstrate the presence of the mycelium in parts of the wood which



73.—*Polyporus igniarius*, from maple.

to the eye appeared sound. The mycelium grew out from the wood into the moist air, along the concentric annual rings, and the medullary rays, so that within 24 hours the location of the mycelium at these points was plainly demonstrated and photographs taken at this time marked the location of the mycelium in the infected areas. In several days time, however, the mycelium spread out between the cut surface forming thin sheets of "punk."

POLYPORUS IGNIARIUS.

This species occurs on broad leaved trees. It is known on the apple, oak, alder, beech, birch, maple and other species. The fruit bodies are hoof-shaped, very hard, almost stony, the upper surface black, while the lower surface, the fruiting surface, is brownish. The upper surface is marked by concentric furrows

and ridges which mark off the annual layers. The fungus is thus perennial.

It is very generally distributed through hardwood forests. It is especially abundant in certain hardwoods in the Adirondacks. In some sections a large percentage of the beech, birch and maple is affected. A quantity of the wood of affected trees was collected both at Childwood, St. Lawrence Co., in 1896, and at Clearwater, Herkimer Co., in 1898. At the latter place, the second flag station north of Fulton Chain, on the N. Y. C. R. R., there were excellent opportunities for studying it on the maple, and for determining the conditions which favor the entrance of the fungus into the heart of the tree. Since the mycelium cannot enter through the living cambium of the tree, an "infection court" must first be provided. These infection areas are provided in a variety of ways, in general their origin being the same as for other timber destroying fungi which enter through wounds.



74.—Section of fruit body of *Polyporus igniarius*.

The conditions prevailing in a large portion of the mixed forests of the Adirondack region are such that a very common point for entrance is provided by the falling of the lower limbs. In the mixed forests the spruces and pines tower so far above the hardwood as to cut off much of the light. The hardwoods are thus so shaded that the area of foliage is considerably lessened, many of the trees having few limbs, and then bearing few leaves compared with trees in the open, or even in a hardwood forest where all the trees have an equal chance for light.

A maple tree about 20 cm. (eight inches) in diameter in the mixed forest at Clearwater had been affected by the *Polyporus igniarius* for a number of years. The fruit body was several years old, of a triangular shelving form, and 15 cm. broad. Several entire sections of the trunk, one of them bearing the fruit body of the fungus, were collected and shipped to Ithaca.

Cross sections of the tree present a very characteristic and often beautiful marking of the wood due to the different stages of decay and the coloration of the wood. The more advanced stages of decay lie at the centre, the less advanced ones toward the periphery. The sound wood at the periphery is limited

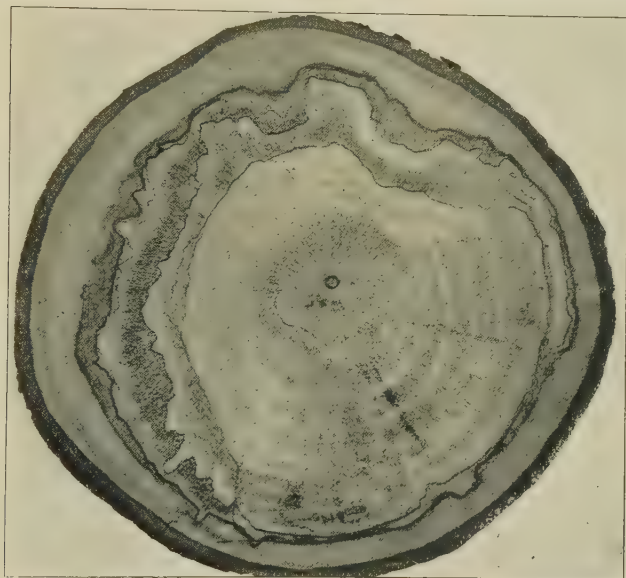
from the decayed area toward the centre by a broad and irregular discolored area. The discolored area is of a light brown color, and this is farther sharply defined from the pale yellowish white area outlined by a narrow black line. The more advanced stages of decay, in this maple tree advanced toward the periphery in separated columns, showing on cross section a radiating or digitate figure. The radiations or "fingers," alternate with dark areas which extend inward from the



75.—Section of maple tree showing effect of mycelium of *Polyporus igniarius*.

periphery as shown in the photograph. Sometimes this figure is quite regular around a portion of the margin, while other portions are very irregular. The decay of the wood seems to proceed in waves from the centre toward the periphery, so that

there appear several different stages. The outer one is marked by the dark discolored area, the next is pale yellowish white, the wood being quite soft, and an older and more advanced area at the centre of the heart. These different stages in the process of decay from the centre to the periphery are usually limited by the black line, which is bordered by a more or less well defined corona of color darker than the area upon which it is advancing.



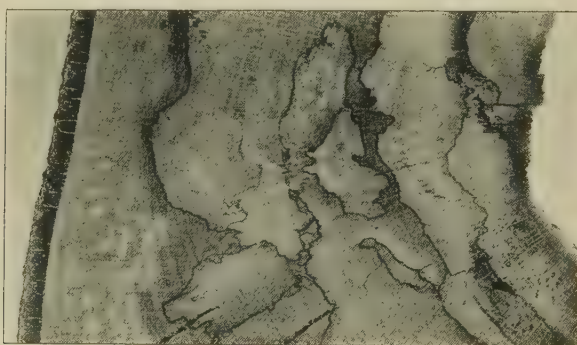
76.—Young trunk of maple nearly killed by *Polyporus igniarius*.

In many cases these areas of decay progress very irregularly, and the figure becomes complicated and confused, especially in the later stages of the decay of a tree, so that dark lines extend very irregularly.

An examination of several maple trees bearing the *Polyporus igniarius* gave evidence that the peculiar discoloration of the wood, accompanied the mycelium of this species of fungus, and might perhaps be sufficient to identify the species even where no fruit form of the fungus was present. An examination of the

trunks of the beech bearing the *Polyporus igniarius* collected at Childwood, N. Y., in 1896, presented the same characteristic coloration and marking. The maple is said by some lumberman to be troubled by a disease which they term "black heart." It would be interesting to know if the coloration produced in the heart by the action of the mycelium of *Polyporus igniarius* is identical with this "black heart" disease.

It now becomes a matter of interest to determine the mode of entrance of the mycelium of this fungus into the tree. The fruit bodies were found to be situated at wounds. These wounds, or places of exit for the fruit form of the fungus, were "knot" holes formed by the dying away of the lower limbs, and the failure of the healing tissue to close the wound thus formed. The fruit form can make its exit through quite a small opening,



77.—Effect of mycelium of *Polyporus igniarius* on wood of beech.

and usually does, growing to larger dimensions outside as it ages. The first year's growth of the fruit form may then be quite small, as in Fig. 79 where it is but a small protuberance 1 to 2 cm. in diameter and showing no fruiting surface. This often increases in size each year, slowly, until 4 to 5 cm. in diameter, when it may increase more rapidly and each year form a new fruiting surface beneath.

The young fruit form shown in the photograph is on a trunk of a maple 10 cm. in diameter. This was the only evidence that the tree was diseased, all the other wounds at fallen limbs

having healed over. A section of the trunk shows that the heart rot had begun. It is in the first stages of the disease and confined to a limited area, that directly at the centre of the heart. There is present here only the discolored area which is characteristic of the other and younger area in older stages of the disease, described above. It is quite likely that the fungus enters at these slow healing wounds where the lower limbs have fallen, and that in some cases the wounds might entirely heal over and imprison the mycelium before the fruit bodies had an opportunity to form. That there was abundant opportunity for the mycelium of the fungus to enter at these wounds is shown by the evidence of a large proportion of the young maple trees in the mixed forest at Clearwater.

I have already called attention to the deep shade in the spruce woods where the tall spruces overtop the broad leaved trees, and of the effect which this shade has in checking foliage development on the younger maples. Even on the young and middle aged maples there are comparatively few branches and these near the top of the tree, the lower branches having died and dropped off. The same can be said of the beeches, birches and other broad leaved trees. Even on these topmost branches there are comparatively few leaves, because of the low light reaction. This means then that a comparatively small amount of the carbohydrates necessary in the formation



78.—Ulcers on trunk of maple.

of cell walls and woody tissue is manufactured. Consequently growth and the formation of wood goes on slowly. This interferes in a striking way with the healing processes needed to cover up the wounds caused by the falling limbs.

When there is an abundance of foliage and light, carbohydrates are formed in sufficient abundance to heal at a rapid rate. The healing tissue is firmer than the normal wood, and working

from within and close to the branch, soon heals over and excludes the mycelium of the timber destroying fungi. On the other hand, when there are few leaves and a small amount of starch is formed the healing process goes on slowly, and before the opening caused by the falling limb can be closed, the portion of the branch exposed undergoes first weathering, and later the mycelium lays hold and enters, reaching the heart of the tree before the barrier of healing tissue is formed. From observations during several seasons it seems that this is a very common mode of entrance for



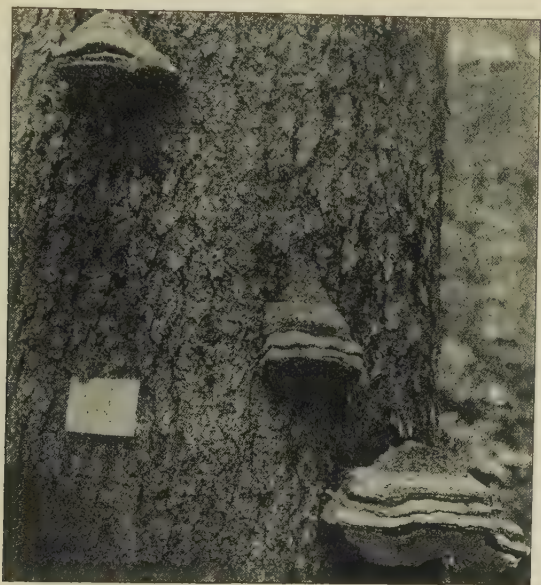
79.—Very young fruit body of *Polyporus igniarius* forming at a branch wound.

the timber destroying fungi in the broad leaved trees.

A number of cases observed at Clearwater offer striking examples of the slowness with which the healing process goes on at branch wounds. The healing tissue formed slowly and did not close up against the base of the branch because of the small percentage of newly formed plant substance. Then for a series of years the healing would cease and an area around the knot would die back. Then for another series of years the healing would begin and advance over a portion of this dead area, when another period would intervene during which a still greater area would die back. In this way large and ugly, open ulcers

are formed, in which the wood within is exposed. This condition is shown in photographs from young maples. On a number of these examples there were no fungus fruit bodies, but a section of the trunk shows all the character of the heart rot caused by the mycelium of *Polyporus igniarius*.

The *Polyporus igniarius* has been known for a long time to inhabit fruit trees, especially the apple, peach, etc., under certain conditions. During August, 1900, I observed an apple tree by the



80.—Fruit bodies of *Polyporus pinicola* on red spruce.

roadside a few miles south of Cortland, N. Y., with fruit bodies of this polyporus on it. A number of years ago the tree had been pruned, by cutting several large limbs near the trunk, and others out some distance from the trunk. The tree was probably diseased at that time, and perhaps these limbs were dead or dying. This may have led to their amputation.

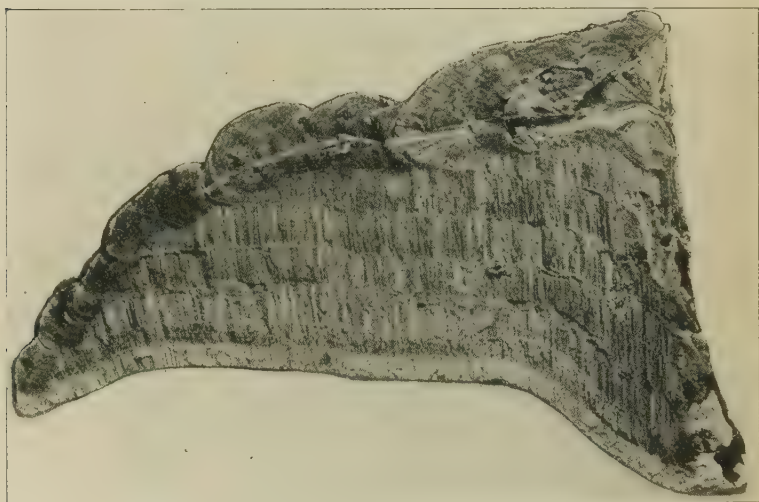
In all cases the fruit bodies of the fungus were formed at these cut surfaces, there being no other place of exit. The tree was probably seriously wounded when young, and the mycelium entering had spread all through the heart of the trunk and

branches, but was unable to form the fruit bodies until the larger limbs were pruned.

Several of the branches of this apple, bearing fruit bodies, were taken for examination. The character of the heart rot is in all essential respects the same as that observed in the maple and beech.

POLYPORUS PINICOLA.

The pine destroying polyporus is widely distributed in the United States and other north temperate regions. It occurs on



81.—Section of fruit body of *Polyporus pinicola*, showing strata of tubes.

various conifers, on the pines, spruces, balsams, larches, etc.

The fruit bodies are shelving, hard and firm, though not so hard as those of *Polyporus igniarius*. They are perennial and therefore single specimens increase in size from year to year, usually becoming broader below and of course thicker from each annual accretion layer.

The fruit body is marked on the upper surface by prominent concentric ridges and furrows. The marginal ridge is the one representing the latest year's growth. The color of the fruit body is from dark brown to nearly black at the base, varying to a reddish brown near the margin. The marginal zone represent-

ing the latest growth varies in color according to the time of collection. When the marginal zone is young it is whitish or yellowish in color, becoming reddish yellow or red later in the season and having then a shining polished surface. The under surface is yellowish white, and on bruising, the yellow color is often more distinct. The pores of the under surface are just visible to the naked eye. On sectioning the fruit body the annual layers seem quite distinct.



82.—Section of fruit body of *Polyporus applanatus*, showing tube strata.

The size and distinctness of these concentric elevations or zones on the upper surface of the fruit body vary according to the rapidity of growth. Where the growth is rapid the zones are large and prominent on the fruit body, increasing rapidly in size each year. One fine specimen collected on a hemlock spruce in the vicinity of Ithaca is 40 cm. broad by 25 cm. long, and is only six or eight years old, there being apparently two imperfect zones which may represent years of very slow and imperfect growth. Of the six annual marginal accretions which are very prominent the measurements are as follows: First, 4 cm.; second, 6 cm.; third, 3 cm.; fourth, 2.5 cm.; fifth, 3.5 cm.; sixth, 4 cm. The usual size of the annual zone is from 2 to 3

cm. Sometimes, however, they are much smaller, from 4 to 8 mm., and then they are not very prominent. In such cases, however, the color character of the different zones and the character of the under surface make it possible to distinguish the plant from others.



83.—*Fruit bodies of Trametes abietis, shelving form.*

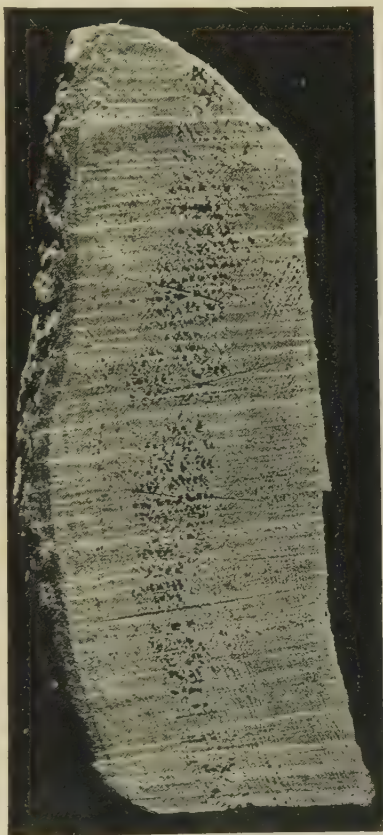
In this and some other forms where the zones are not very distinct it is occasionally difficult to separate the species from forms of *Polyporus applanatus*. In the latter species the tube surface is sometimes yellowish. In the fresh condition, if a bruise or scratch occurs on the tube surface of *Polyporus applanatus* the exposed parts at once change to a dark brown or blackish color. When dry, however, this test will not yield the

results desired, but section the plant through the middle perpendicularly and compare the color and structure of the tube strata. In *Polyporus applanatus* the strata are deeper and very clearly differentiated. They are also of a dark gray, or hair-brown color, while the tube strata of *Polyporus pinicola* are whitish or yellowish-brown, and while clearly differentiated are not so distinctly so as in *Polyporus applanatus*.

The fruit bodies of *Polyporus pinicola* are sometimes found on the trunks of living trees but much more frequently they do not appear until the tree is dead. They are quite common on dead standing trunks and stumps and on fallen logs. They continue to grow after the tree is dead and in quite an advanced stage of decay.

In wood which is in quite an advanced stage of decay, extensive sheets of mycelium forming "punk" are often in the crevices formed by the checking of the wood. These sheets of punk are very similar to those formed by *Polyporus sulphureus* in deciduous as well as in coniferous trees. In the large number of cases

in which I have found these sheets of punk in rotten logs or decaying tree trunks of conifers in the Adirondack mountains, I have not found any fruit bodies of the *Polyporus sulphureus*. Since these sheets of punk found in conifers are



84.—"Dozed" place in butt of red spruce from mycelium of *Trametes abietis*.

usually ascribed to this species, I searched diligently for specimens on the trees. In no case in the Adirondacks have I yet found *Polyporus sulphureus* on conifers, although it probably does occur on them. This suggested that the sheets of punk in the conifers examined were connected with *Polyporus pinicola*, and many examples were studied in an endeavor to trace the connection of the sheets of punk in the trunk with the fruit bodies on the exterior.



85.—Dead stub of red spruce
where the mycelium entered.

The direct connection was difficult to trace although in most examples it was not difficult to trace the punk through the log radially to the bark, but at this point in splitting the bark radially the direct connection of the punk was not seen. The most favorable examples for study were those in which the fruit body was just originating as a tubercle 4 to 6 cm. in thickness on the outside of the bark. In splitting several of these from the tree a circular patch of the punk was found on the inner surface of the bark and looked very much as if the mycelium issuing from the tree and connected with the fruit body had been riveted on the inner surface of the bark, but on splitting such structures radially no evidence of

the connection of the bark with the fruiting body was presented. However, on splitting the bark tangentially successive sheets of punk were found between the inner sheet and the fruit body. These sheets at certain points extended obliquely and connected so that they formed a zig-zag connection. The firm layers of the bark prevented the direct radial exit of the mycelium, but by working in a zig-zag fashion between the bark layers it was enabled to make its exit. Having discovered this, it then became

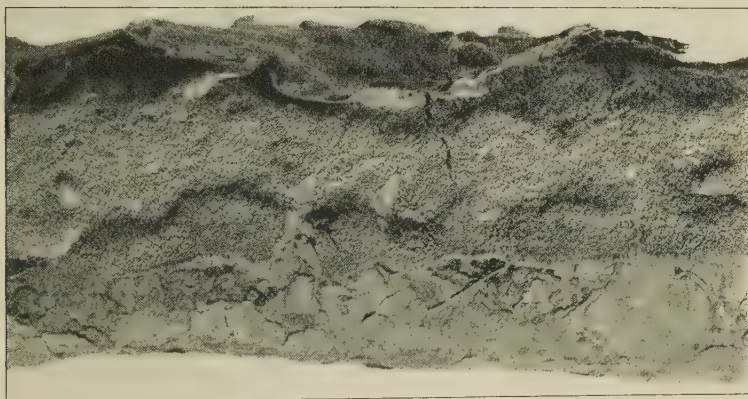
an easy matter to trace the connection of the punk in the log with the fruiting body in all cases.

POLYPORUS PINICOLA ON BROAD-LEAVED TREES.

I have not found any record of *Polyporus pinicola* on broad-leaved trees. I have, however, found it on three different species in the Adirondack Mountains, on the beech (*Fagus ferruginea*), the birch (*Betula lenta*), and the maple (*Acer saccharum*).

TRAMETES ABIETIS.

This plant is common on spruces and balsams. It is a shelving form, and much smaller than the species of *polyporus* just



86.—Fruit body of *Trametes abietis* spread out on surface of limb.

described. The caps stand out from the wood 2 to 5 cm., are somewhat triangular in side view, and broader than long. The base is usually spread out where it is attached to the tree, and often the entire plant is spread over the surface of the wood. In this case no shelf form is developed. The upper surface of the shelf is marked by concentric furrows and ridges, and is more or less velvety or hairy. When young the fruit bodies are tawny in color, but in age they become a darker brown, especially above, while the fruiting surface is a yellowish brown.

TRAMETES ABIETIS ON THE RED SPRUCE.

An interesting example of a red spruce (*Picea rubra*) was examined during September, 1898 in the Adirondack mountains. This was near Nehasena, Herkimer Co., on the tract owned by Dr. Seward Webb. Through the courtesy of Prof. C. S. Graves, who then had the supervision of the forestry operations on this tract, I had the privilege of following the lumberman for two days to inspect trees, or portions of trees, which were discarded after they had been felled.

In this particular case the entire tree had been discarded, although two logs had been cut from the trunk. On approaching the tree I first came upon the stump, and searched here for some evidence of the reason for rejecting the timber. Near the periphery of the stump, in the older sap wood near its junction with the heart wood was a crescent shaped area in cross section about 3 cm. broad and 15 cm. long. This was distinctly marked off from the surrounding portion by the coarser fractures of the wood by the cross cut saw used in felling the tree. This indicated that the wood was here slightly "dozed." The remainder of the stump was sound. This small area showing such a slight alteration in the wood probably would not have been considered objectionable.



87.—Pockets of decayed tissue in limb of red spruce.

On examining the cut made for the first log, 16 feet above, the entire heart proved to be badly decayed. A large part of the sap wood was also invaded, and the cambium was being encroached upon. There remained only a thick shell of living and unaffected tissue underneath the bark. The heart wood was so soft that the fracture from the saw teeth was irregular, roughly cut and partially "ironed" down by friction from the

saw blade. Still another log above this one had been cut off by the woodmen in the hope that the heart would be sound, and that a good log could be obtained near the top. This cut, how-

ever, presented a condition similar to the first one, the heart and sap wood were badly decayed. This condition was sufficient to cause the abandonment of the entire tree. There were no evidences on the trunk, below the branches, of the fruit bodies of any fungus, nor of any injury which might have afforded



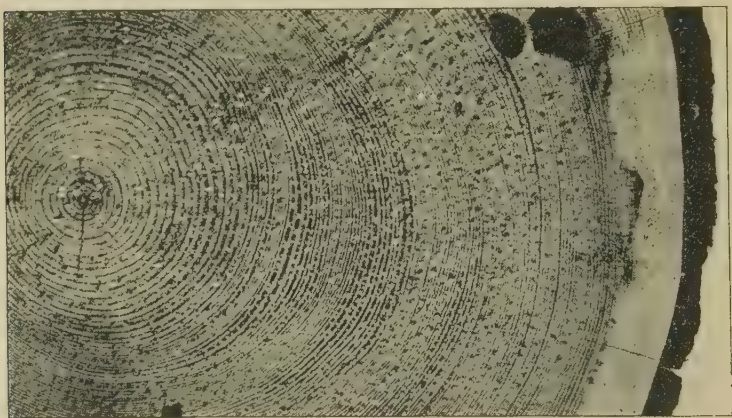
88.—*Pockets of decayed tissue in trunk of red spruce.*

an entrance for the fungus. The cut ends of timber were so badly roughed up by the saw that no structural characters in the diseased timber which might aid in the determination of the species of fungus could be seen. The next step was to determine the fungus and the place where it entered the tree.

Since the decay at the stump was so slight, and the diseased area so small in comparison with the extensive injuries farther up in the trunk it was quite evident the fungus had not entered from below. Upon searching in the top of the fallen tree, it was found that the "leader" of the tree when about 5 cm. (2 inches) in diameter had been broken off, possibly by a falling

tree, 30 or 40 years ago. This leader, as a dead, decorticated object still projected 15 to 20 cm. above the point where the healing process was going on (Fig. 85). One of the upper branches at this point had become the leader.

This old fracture of the main trunk years ago very probably provided an opportunity for the entrance of the fungus. Most conifers are provided with a quantity of free resin in the young branches or shoots, or the growing portion of the trunk. As is well known this resin flows freely from fresh wounds, and often continues for some time from old ones. The presence of this

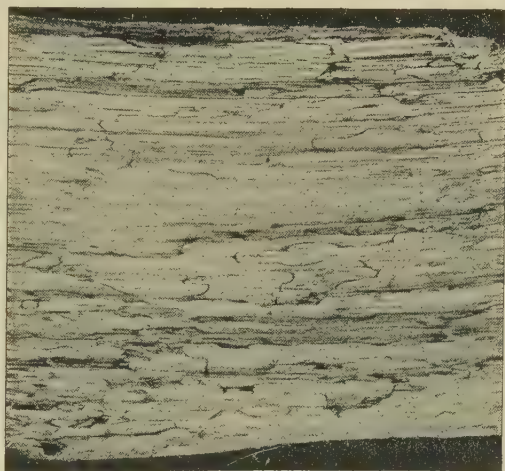


89.—Cross section of red spruce showing pockets from end view.

resin and its free exudation from wounds is nature's most effective method of blocking the way to the entrance of timber destroying fungi in the conifers. When the wound is small, or the broken branch or shoot is young, the amount of resin forms an effectual barrier against the entrance of this class of fungi. Where the wound is larger, or the shoot is older, the process of healing over requires many years, and the older portions of the wood do not yield so great an amount of free resin.

The broken shoot in this example was 5 cm. (2 inches) in diameter. Healing began 20 to 30 cm. below the broken end. After 30 or 40 years the dead prong still projected 15 to 20 cm. above the healing surface, and probably never would have healed

over. During this long time the fungus mycelium had an opportunity to enter, travel down the heart wood of the trunk and reach the butt. It is interesting to observe that while the fungus mycelium gained entrance through the broken area of the leader in the top of the tree, and traveled downward, the greater injury to the trunk was some distance below. This is probably due to the greater amount of free resin in the younger portion of the trunk above. While the mycelium traveled downward through this, it did not spread rapidly here nor bring about such a complete disintegration of the tissue. Sections of the trunk just below the point where the fungus entered, and for some distance below, show the heart wood is finer and harder though invaded by the mycelium. The wood is also very much stained, brown irregular areas often marked off by black lines,



90.—Rotten section from rotted log of red spruce.

or divided up into smaller areas by black lines. The mycelium also traveled upward in the newly established leader of the tree. From the trunk it had invaded many of the branches in the same way. As is usual in such cases a number of the branches had been killed. These dead branches then yielded readily to the disintegrating action of the fungus.

On a few of the limbs fruit bodies of *Trametes abietis* were found. A branch bearing a fruit body and broken at this point shows the gross structural characters of the wood affected by the mycelium of this species. This is shown in the photograph. At one stage in the decay of the wood there are numerous areas

in which the process of disintegration is localized, or where it proceeds much more rapidly than in the surrounding wood. These isolated centres are quite evenly distributed. The wood is broken down completely, and largely consumed, leaving a partial skeleton, or nearly all of it having disappeared. The remnant, as well as a thin layer of the bordering tissue, is bleached and white. It is thus in strong contrast with the reddish color of the surrounding wood where the decay has been checked or has proceeded more slowly. This rapid local disintegration, then, forms numerous small "pockets" distributed through the affected wood at a certain stage in the progress of the disease. They are plainly visible because of the bleached tissue.

These pockets are a characteristic feature in one stage of the heart rot of the spruce from the mycelium of *Trametes abietis*. If they are found in the heart wood of the trunk of this individual spruce it would be quite conclusive evidence that the heart rot here was caused by this fungus, and that the infection having occurred at the broken trunk in the top of the tree many years ago had gradually spread down the trunk to the base and out into numerous branches, some of which have been killed as result. Sections of the trunk of this tree were cut out at different places and shipped to Ithaca for study.

On splitting sections of the trunk cut from the discarded logs, these characteristic pockets were found to be present, and Fig. 88 is from a photograph of a small block.



91.—Badly pruned oak tree.

These occur in the

portions of the trunk where decay has made considerable progress, the entire heart being invaded, and the fungus encroaching on the "sap" wood. When cut with the cross-cut saw, or even with a finer saw, the ends of the blocks do not show the pockets, since the soft wood is so readily fractured by the teeth of the saw. But when the end of a block is planed off smooth the pockets in transection are quite distinctly brought to view. They are shown in the photograph. From a side and end view shown in the photographs the pockets are seen to be oblong in side view and cylindrical in cross section. They are 2 to 3 mm. broad and 4 to 6 mm. long. In the younger portions of the trunk, some distance above the size where logs were cut, and below the point of

entrance of the fungus, and thus nearer it, the pockets were not yet formed. This is probably due to the fact that while the mycelium first penetrated the heart wood here, the latter being younger was more resistant, and the process of disintegration proceeded less rapidly. The pockets appearing on certain of the branches is accounted for by the fact that these branches had been killed for some time, and were consequently in a less resistant condition.



92.—Result of bad pruning of hickory, the limbs have rotted out allowing entrance of fungus mycelium.



93.—Proper way to prune, wounds healing up properly.

The formation of pockets by the rapid disintegration of the tissues at many centers recalls the "peckiness" of cypress wood caused by the mycelium of a fungus yet unknown. The pockets

in the cypress wood are much larger, however, and the structural character of the affected wood is quite different. In the case of the cypress trunks affected with this disease known as "peckiness," it is believed that the fungus, while developing at the centres, excretes an enzyme or "ferment," which permeates the surrounding wood and acts as an antiseptic which prevents the further disintegration. It is possible that this is to some



94.—Shade tree used as a hitching post.

extent the case in the formation of the pockets in the spruce timber, that is, that the wood intervening between the centers of rapid disintegration, becomes permeated with an enzyme excreted by the mycelium which renders it immune for a time, or at least retards the disintegration of the wood. But if this is the case, the effect of the antiseptic is not lasting. In the case of fallen logs affected by the *Trametes abietis* the decay continues until all parts of the wood are in a much decayed condition. Still, in such logs, it is quite evident that the progress of the disintegration has been intermittent, certain centres having first decayed, and in time spreading from these pockets to surrounding areas until all the wood is brought under complete contribution to the mycelium. In such decayed spruce wood, there are further evidences that the decay has spread from numerous centers which have been extended until they finally met. This is shown in the varying coloration of the wood, and especially by black boundary or limiting lines. (Fig. 90.)

It is evident from these and similar studies that there is no cure for the diseases caused by wound parasites after once the fungus has entered through the wound into the interior of the tree. For a few years there may be no apparent injury but with the lapse of time the tree becomes badly injured

if not destroyed. The trees may live for years, or even a century or more with the fungus inside still growing. They may be so weakened that they are broken down or uprooted during strong winds. Shade trees may be rendered unsightly, and lacking in density of foliage. Fruit trees may be rendered less fruitful if not ultimately killed. Timber trees in a very few years may be so injured as to be worthless for the market.

In their relation to forestry these studies emphasize the desirability of careful and economical methods in the felling of timber to protect the young stand from injury, in the supply of light to the forest floor, and in the protection from fire. For while many forest fires may not be so severe as to kill the trees outright the fire often scorches exposed roots, or the base of trunks, where the leaves are thick, or by a dead and dry log or stump, thus affording an entrance for these wound parasites.

In the handling of fruit and shade trees there should be the greatest care from the nursery stock to the fruiting tree to prevent wounds. In pruning operations especially should there be care in pruning smooth and close to the trunk, followed by the use of some antiseptic wash, or lead paint.

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